William Nordhaus' 2018 Nobel Prize in Economics: Integrating Climate Change into Long-Run Macroeconomic Analysis

Emanuele Massetti

School of Public Policy

Georgia Institute of Technology

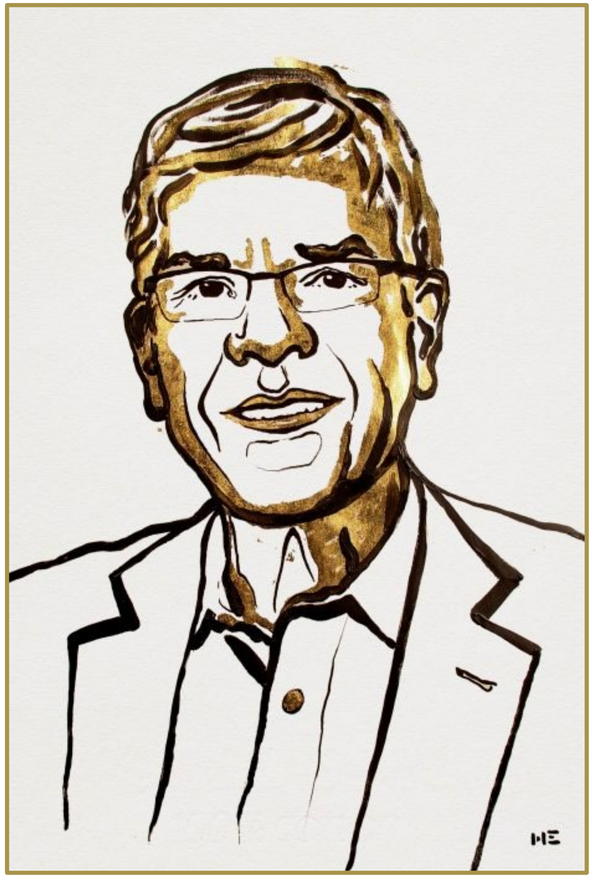
November 27, 2018

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2018

Ill. Niklas Elmehed. © Nobel Media

William D. Nordhaus

"for integrating climate change into long-run macroeconomic analysis"



Ill. Niklas Elmehed. © Nobel Media

Paul M. Romer

"for integrating technological innovations into long-run macroeconomic analysis."

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MLA style: The Prize in Economic Sciences 2018. NobelPrize.org. Nobel Media AB 2018. Mon. 26 Nov 2018.

1970's: End of The Growth Miracle

- Economic growth slows down
- Trade-offs between economic growth and the environment

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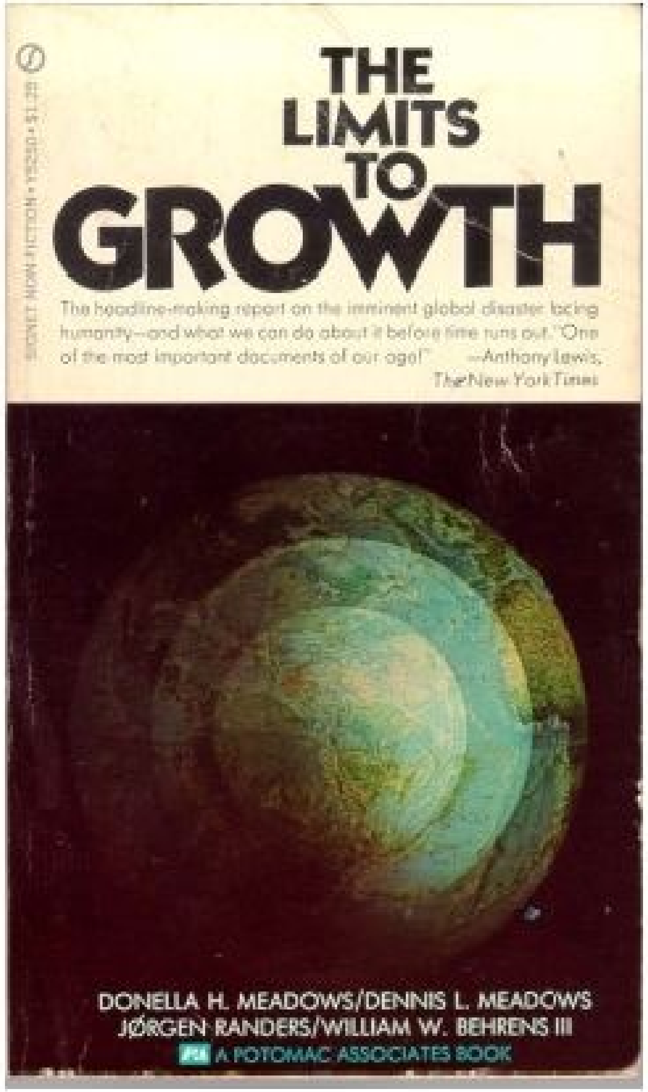
- 1972: publication of the "Limits to Growth"



1970's: End of The Growth Miracle

- Economic growth slows down
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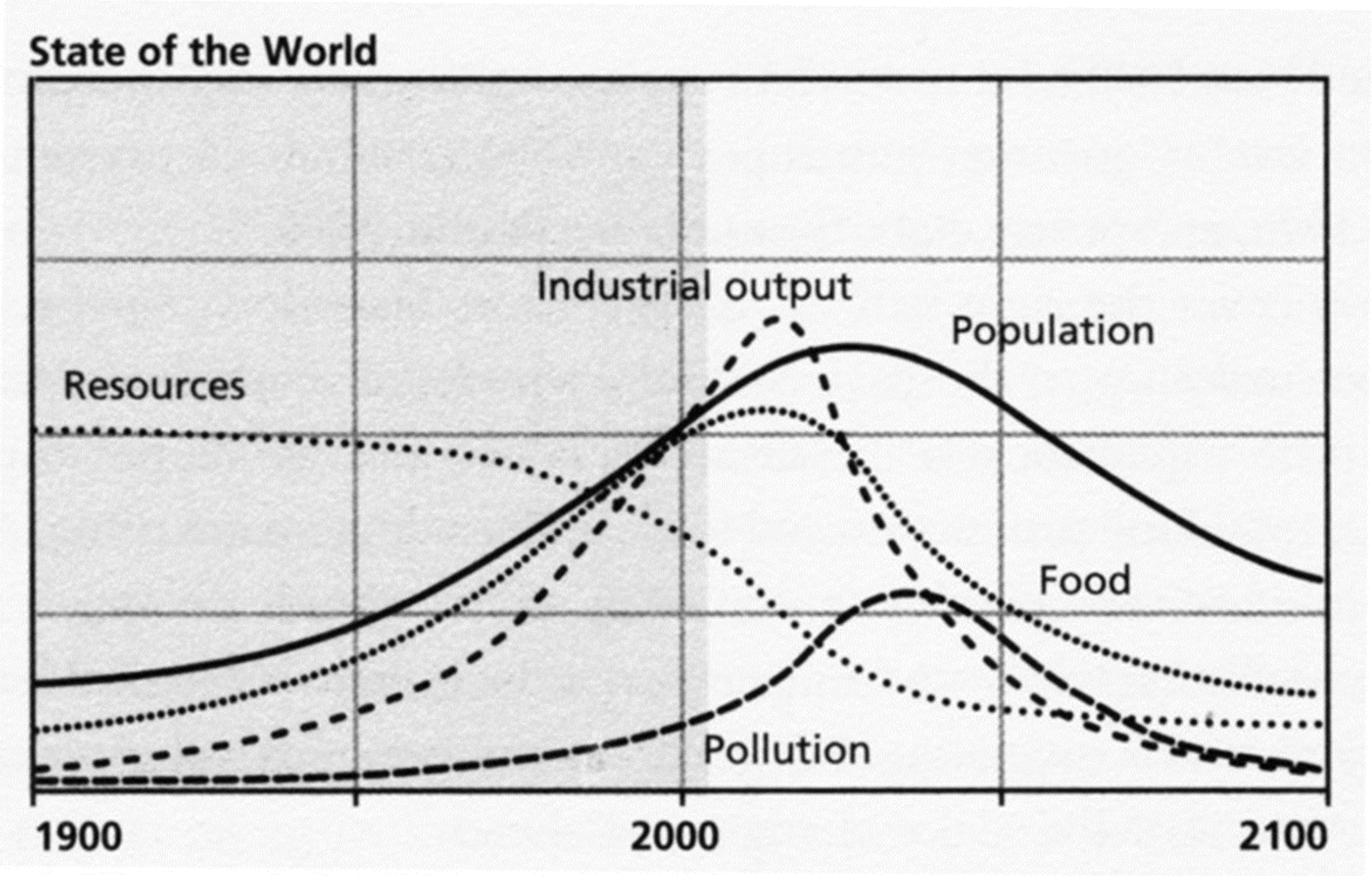
- 1972: publication of the "Limits to Growth"
- 1972: UN Conference on the Human Environment (Stockholm)

Forecasts of Ending Prosperity



The limits to growth, 1972

1972-1974 Natural Resources and Long-Term Economic Growth

Resources as a Constraint on Growth

By WILLIAM D. NORDHAUS*

Is Growth Obsolete?

William Nordhaus and James Tobin
Yale University

WILLIAM D. NORDHAUS
Yale University

The Allocation of Energy Resources

Foundation. I am grateful for helpful comments by Gary Haller, Tjalling C. Koopmans, Alan S. Manne, and members of the Brookings panel. In addition, Paul Krugman provided research assistance extraordinary. Remaining errors are, of course, my responsibility.

1973: Sharp Critique of the Limits to Growth

WORLD DYNAMICS: MEASUREMENT WITHOUT DATA[1,2]

I. INTRODUCTION

- Not a single relationship or variable is from actual data or empirical studies
- Simulation data not subjected to empirical validation are void of meaning
- Lack of true multidisciplinary efforts

> ***"If there is sufficient substitutability between producible and non-producible resources and if the price system is functioning adequately, the inevitable collapse predicted by Forrester will be avoided."***

1975: Economic Growth Meets Climate Change

- 1974-1975: IIASA Energy Program

"My own first serious research on global warming started when I spent a year in Vienna at IIASA [...]"

"Research on global warming is deeply interdisciplinary, and IIASA at that time was uniquely able to foster interdisciplinary work. It was here that I published my first (and I believe the first) economic model of global warming as an IIASA working paper in 1975."

http://www.iiasa.ac.at/web/home/about/alumni/News/181008-nordhaus.html

1975: Economic Growth Meets Climate Change

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[..]when he was a research scholar in Austria doing energy research and happened to share an office with a climatologist, who told him, " 'This is where energy research is going to be going,' " Nordhaus remembers. "I said, 'Well, OK, tell me about it.' And that's how it started."

Despite some scientific interest in climate change at the time, the topic "was zero on the intellectual Kelvin scale in economics," Nordhaus says. "There was nothing at that point."

https://www.npr.org/2014/02/11/271537401/economist-says-best-climate-fix-a-tough-sell-but-worth-it

The Carbon Dioxide Problem

- Nordhaus, W. D. (1977). Economic growth and climate: the carbon dioxide problem. The American Economic Review, 67(1), 341-346.

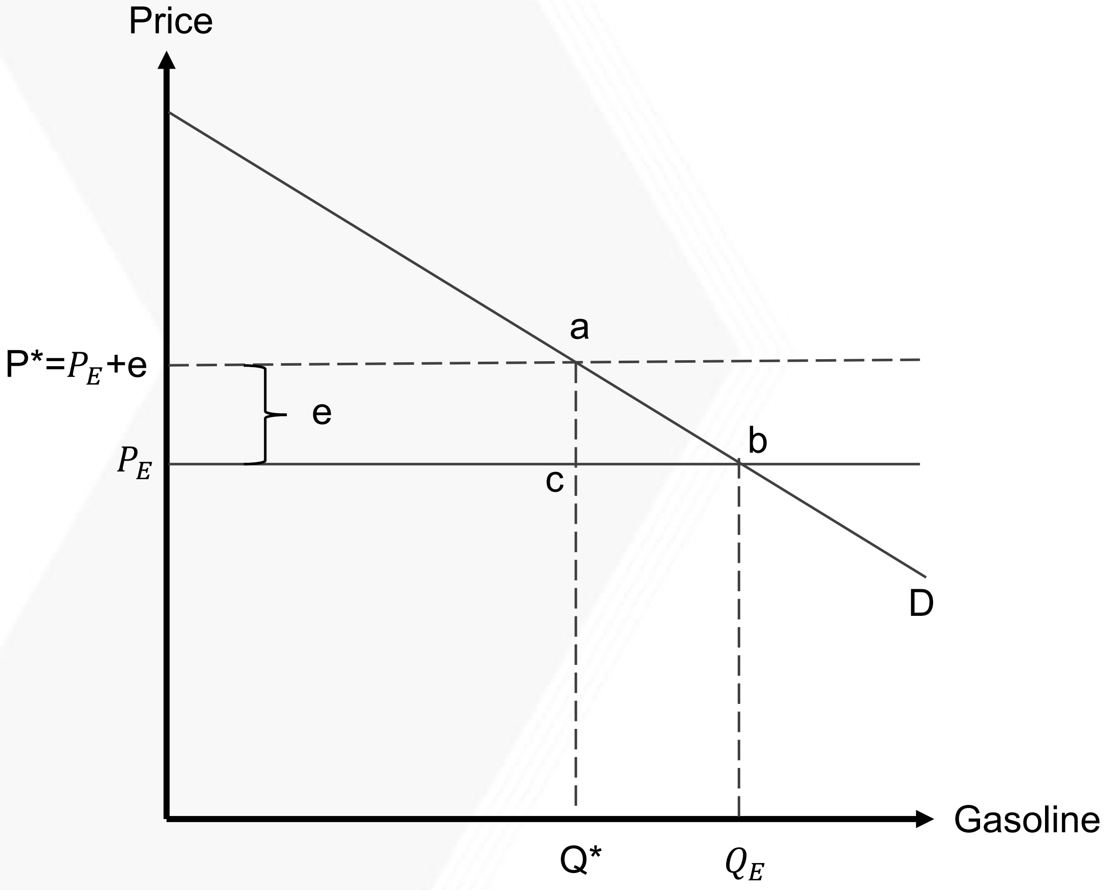
"One persistent concern has been that man's economic activities would reach a scale where the global climate would be significantly affected."

"It appears that the uncontrolled path will lead to very large increases in temperature in the coming decades, taking the climate outside of any temperature pattern observed in the last 100,000 years."

The Carbon Dioxide Problem

- GHG emissions are an “externality”
  - The cost of increasing GHGs concentrations mostly falls on other individuals
- Externalities are a market failure
  - The polluter does not “own” the full consequences of releasing emissions
  - Free-lunch
  - Excessive level of emissions
- Carbon-dioxide emissions are the “perfect” externality
  - Global effects
  - Long-lasting effects

Economic Externalities



- Demand function as a measure of the gross benefit from consumption
- P_E private cost
- Q_E market equilibrium

- e external damage of one unit of gasoline
- P* social cost

- Triangle abc measures welfare loss
- A tax equal to e restores efficiency

Economic Efficiency

- Marginal cost/benefit: cost/benefit of one additional unit of consumption/investment

- Economic efficiency (optimality) is the fundamental principle in economic analysis
  - Marginal cost = marginal benefit

- The cost of reducing carbon-dioxide emissions by one additional unit must be equal to the benefit not releasing that unit from the atmosphere

- This is a very complex problem that requires knowing
  - Costs
  - Benefits (avoided damages)
  - In a dynamic long-run global setting

Cost-Effectiveness

- Economic efficiency selects the “optimal” (efficient) level of concentrations in the atmosphere

- Cost-effectiveness is less ambitious
  - Choose a desired level of concentrations
  - Achieve this goal at the least cost

- Economic efficiency implies cost -effectiveness but not vice versa

A Simple Integrated Assessment Model

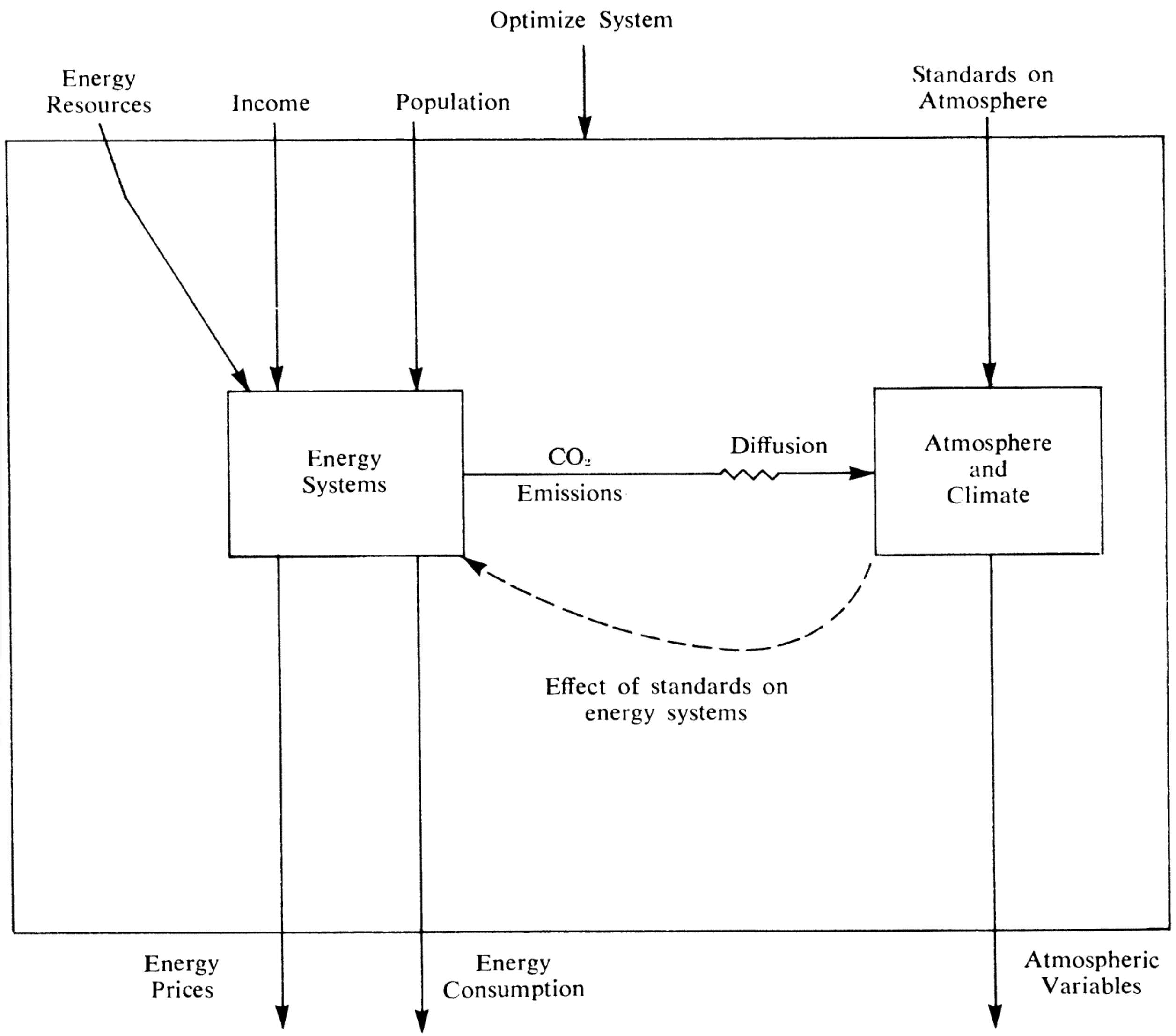


FIGURE 2. OVERVIEW OF MODEL OPTIMIZING THE ENERGY-ENVIRONMENT SYSTEM

Nordhaus, W. D. (1977). Economic growth and climate: the carbon dioxide problem. The American Economic Review, 67(1), 341-346.

This Changed the Way in Which Models are Used

- Pioneering modeling of interactions between economic growth and climate change
  - A carbon-circulation model to track carbon -dioxide concentration
  - A climate model that describes climate change as function of concentrations
  - An economic model in which output is produced using capital, labor and energy
- Solving a model with three different integrated systems was a challenge
  - Use of computer simulations instead of analytical solutions
- We call this framework Integrated Assessment Model
  - Main advantage: consistent scenarios for economic, energy and climate systems

Stabilization

TABLE 1—ENERGY CONSUMPTION, CARBON EMISSIONS, AND CARBON EMISSION TAXES

	1970 (Actual)	1980	2000	2020	2040	2100
Energy Consumption, United States, 10^{15} btu/yr						
Uncontrolled CO_2	71	76.	92.	155.	250	395.
100 percent increase CO_2		76.	92.	142.	160.	405.
Global Carbon Emissions, 10^9 tons/yr						
Uncontrolled CO_2	4.0	6.9	10.7	18.4	40.1	45.4
100 percent increase CO_2		6.9	10.7	16.6	16.0	4.9
Carbon Emission Tax ($/ton)						
Uncontrolled CO_2	.00	.00	.00	.00	.00	.00
100 percent increase CO_2		.14	1.02	8.04	67.90	87.15

Notes: Carbon emissions are tons of carbon dioxide, carbon weight, while carbon taxes are calculated dual variables in the efficient program, and have the dimension of 1975 dollars per ton carbon weight of emission. Source is Nordhaus (1976).

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Nordhaus, W. D. (1977). Economic growth and climate: the carbon dioxide problem. The American Economic Review, 67(1), 341-346.

TABLE 2—COST OF CARBON DIOXIDE CONTROL PROGRAMS

	Path			
	1 Uncon-trolled	2 200% Increase	3 100% Increase	4 50% Increase
Discounted Total Cost, Billions of 1975 Dollars	\$0	\$30	\$87	\$540
Discounted Total Cost as Percent of Discounted World *GNP*	0%	.06%	.12%	.81%

Source: Nordhaus 1976.

- The first model in 1977 studies cost-effective solutions
- No damage functions
- Efficiency cannot be established

Nordhaus, W. D. (1977). Economic growth and climate: the carbon dioxide problem. The American Economic Review, 67(1), 341-346.

Optimism, with Reservations

"Subject to the limitations of the techniques used here, we can be relatively optimistic about the technical feasibility of a carbon dioxide control strategy."

The two central questions that remain to be answered are:

"How costly are the projected changes in (or the uncertainties about) the climate likely to be, and therefore to what level of control should we aspire? "

"How can we reasonably hope to negotiate an international control strategy among the several nations with widely divergent interests?"

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The DICE Model

- 1975-1977: the Provisional Model
  - A detailed energy sector derived from previous work
  - No feedback of the climate on the economy
  - Path of economic growth is given
  - Study of cost of reducing emissions

- 1994: the Dynamic Integrated Climate Economy (DICE) model
  - Still used today and updated regularly
  - Integrated in an optimal (efficient) growth framework
  - Impacts of the climate system on the economy
  - Analysis of optimal (efficient) climate policy: what emissions should be

The RICE Model

- 1996: The Regional Integrated Climate Economy (RICE) model
  - Multi-regional model
  - Regions can choose to cooperate by considering damages to other regions caused by own emissions (Cooperative solution)
  - Regions can behave non-cooperatively, by ignoring damages to other regions (Nash equilibrium)

- Opens the possibility to test with simulations the growing literature on non-cooperative game theory applied to climate change
  - The cooperative solution solves the climate problem
- Analysis of efficient distribution of mitigation effort

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Example of Ouput

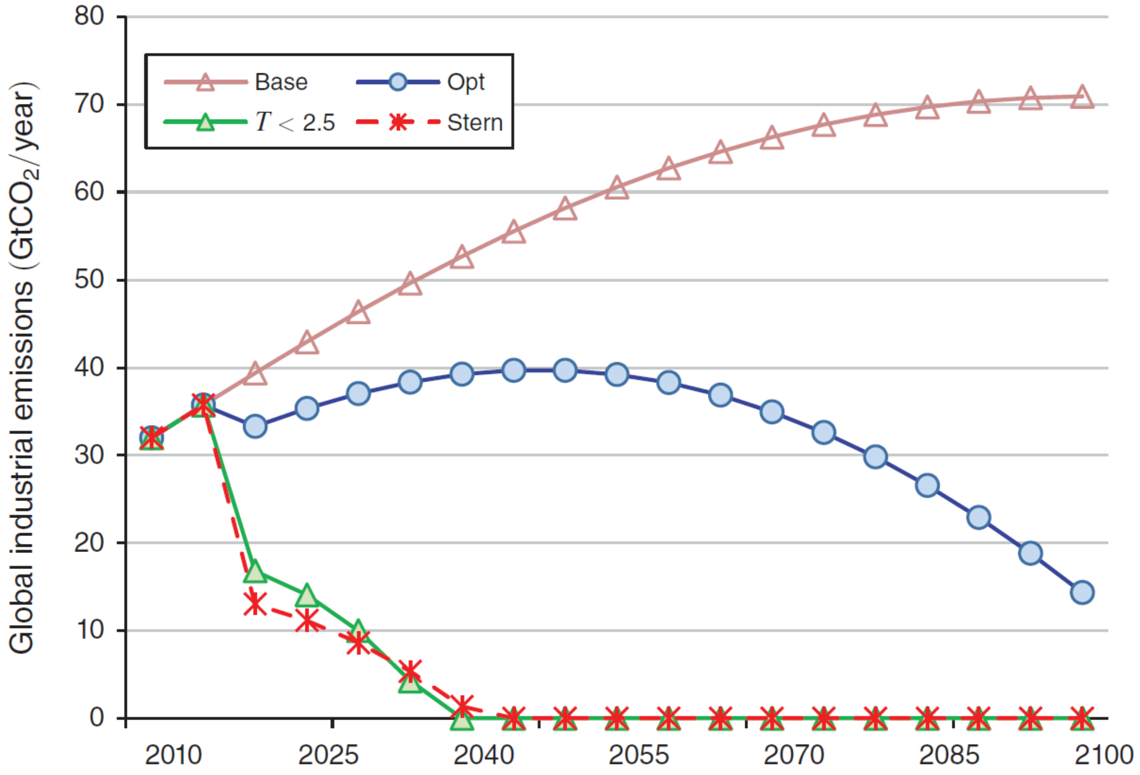

FIGURE 2. ACTUAL AND PROJECTED EMISSIONS OF CO_2 IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios require zero emissions before mid-century.

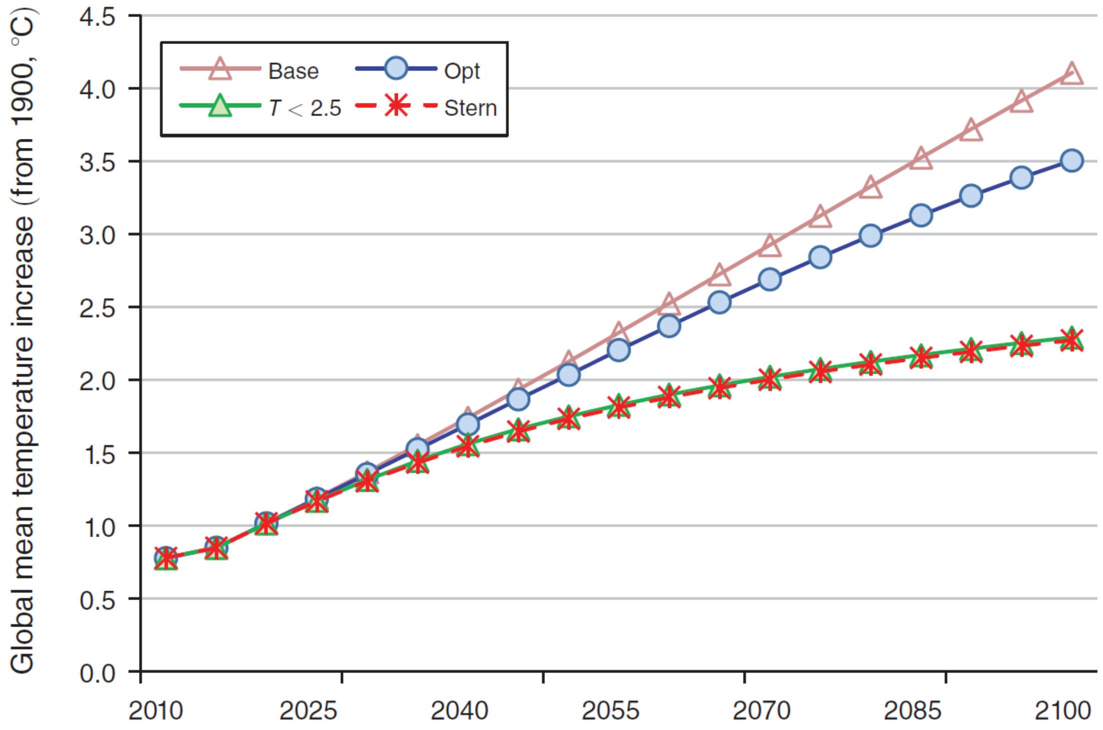

FIGURE 4. TEMPERATURE CHANGE IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios cannot limit temperature to 2.5°C in the best-guess projections.

Nordhaus (2018)

Six Important Take-Away Messages

1. Natural resources and environmental pollutions in the context of long-run economic growth

2. Climate change problem as an inter-generational investment and consumption dilemma

3. Technological change as key driver of long-run growth

4. Economic efficiency as guiding principle

5. Central role of carbon prices

6. International cooperation for climate change

A Cool Head in the Service of a Warm Heart

“His calm approach has at times infuriated environmental activists, who are dismayed at the pace of global action.”

"What can I say about calm?" he replies when asked about that.

"I like to think of the economics as a cool head in the service of a warm heart, and that's my approach to this.“

https://www.npr.org/2014/02/11/271537401/economist-says-best-climate-fix-a-tough-sell-but-worth-it

The 2018 Fourth National Climate Assessment

Where we learn why keeping a cool head is important and where we develop intuitions on economic damages and discounting

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The New York Times

U.S. Climate Report Warns of Damaged Environment and Shrinking Economy

Fighting the Camp Fire this month in Magalia, Calif. Justin Sullivan/Getty Images

By Coral Davenport and Kendra Pierre-Louis

Nov. 23, 2018

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"A major scientific report issued by 13 federal agencies on Friday presents the starkest warnings to date of the consequences of climate change for the United States, predicting that if significant steps are not taken to rein in global warming, the damage will knock as much as 10 percent off the size of the American economy by century's end."

"The report puts the most precise price tags to date on the cost to the United States economy of projected climate impacts: $141 billion from heat-related deaths, $118 billion from sea level rise and $32 billion from infrastructure damage by the end of the century, among others."

A Case of False Perceptions

- Nowhere in the Summary Findings, nor anywhere else in the text, one can find estimates of damages equal to 10% of GDP in 2100
- NCA4 estimates economic losses equal to a fraction of a percentage point in 2100
- 10% losses come from bad reporting and less than ideal writing of the report (more on this later)
- Unfortunately, extreme emissions scenario (RCP8.5) is used as business as usual scenario without understanding the underlying implications

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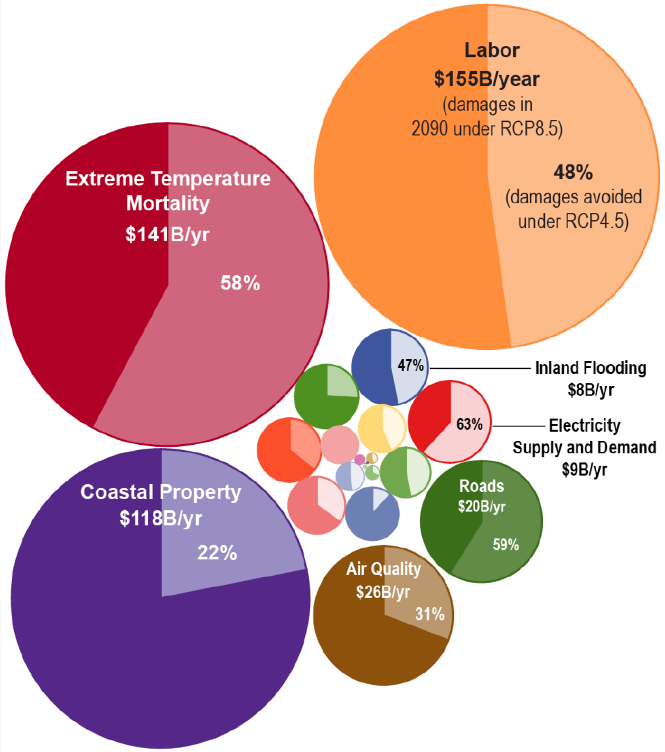
Projected Damages and Potential for Risk Reduction by Sector



Annual Economic Damages in 2090		
Sector	Annual damages under RCP8.5	Damages avoided under RCP4.5
Labor	$155B	48%
Extreme Temperature Mortality◊	$141B	58%
Coastal Property◊	$118B	22%
Air Quality	$26B	31%
Roads◊	$20B	59%
Electricity Supply and Demand	$9B	63%
Inland Flooding	$8B	47%
Urban Drainage	$6B	26%
Rail◊	$6B	36%
Water Quality	$5B	35%
Coral Reefs	$4B	12%
West Nile Virus	$3B	47%
Freshwater Fish	$3B	44%
Winter Recreation	$2B	107%
Bridges	$1B	48%
Munic. and Industrial Water Supply	$316M	33%
Harmful Algal Blooms	$199M	45%
Alaska Infrastructure◊	$174M	53%
Shellfish*	$23M	57%
Agriculture*	$12M	11%
Aeroallergens*	$1M	57%
Wildfire	−$106M	−134%

NCA4. Report in Brief. Ch 29, p. 170.

	RCP 8.5	RCP 4.5	Damages avoided under RCP 4.5
Labor	$ 155.00	$ 74.40	48%
Extreme temperature mortality	$ 141.00	$ 81.78	58%
Coastal Property	$ 118.00	$ 25.96	22%
Air Quality	$ 26.00	$ 8.06	31%
Roads	$ 20.00	$ 11.80	59%
Electricity Supply and Demand	$ 9.00	$ 5.67	63%
Inland Flooding	$ 8.00	$ 3.76	47%
Urban Drainage	$ 6.00	$ 1.56	26%
Rail	$ 6.00	$ 2.16	36%
Water Quality	$ 5.00	$ 1.75	35%
Coral Reef	$ 4.00	$ 0.48	12%
West Nile Virus	$ 3.00	$ 1.41	47%
Freshwater Fish	$ 3.00	$ 1.32	44%
Winter Recreation	$ 2.00	$ 0.21	11%
Bridges	$ 1.00	$ 0.48	48%
Munic. And Industrial Water Supply	$ 0.32	$ 0.10	33%
Harmful Algal Blooms	$ 0.20	$ 0.09	45%
Alaska Infrastructure	$ 0.17	$ 0.09	53%
Shellfish	$ 0.23	$ 0.13	57%
Agriculture	$ 0.01	$ 0.00	11%
Aeroallergens	$ 0.00	$ 0.00	57%
Wildfire	$ (0.11)	$ 0.14	-134%
Total	**$ 507.83**	**$ 221.37**	

NCA4. Report in Brief. Ch 29, p. 170.

USA

RCP	SSP	ΔT (°C) (baseline)	ΔT (°C)	GDP in 2020 (Billion 2015 $)	GDP in 2100 (Billion 2015 $)	Damages in 2100 (Billion 2015 $)	Annual Damages (% GDP in 2100)	GDP in 2100 (% GDP in 2020)	GDP in 2100 with damages (% GDP in 2020)
RCP 4.5 damages	SSP 1	3.0	2.7	$ 17,860	$ 65,023	$ 221	0.34%	364%	363%
RCP 4.5 damages	SSP 2	3.8	2.6	$ 17,904	$ 58,195	$ 221	0.38%	325%	324%
RCP 4.5 damages	SSP 3	4.1	2.6	$ 17,236	$ 31,772	$ 221	0.70%	184%	183%
RCP 4.5 damages	SSP 4	3.8	2.5	$ 17,972	$ 48,654	$ 221	0.45%	271%	269%
RCP 4.5 damages	SSP 5	5.1	2.7	$ 18,193	$ 135,317	$ 221	0.16%	744%	743%
RCP 8.5 damages	SSP 5	5.1	5.1	$ 18,193	$ 135,317	$ 508	0.38%	744%	741%
RCP 8.5 high damage	SSP 5	5.1	5.1	$ 18,193	$ 135,317	$ 13,532	10.00%	744%	669%

RCP	SSP			GDP pp in 2020 (2015 $)	GDP pp in 2100 (2015 $)	Damages pp in 2100 (2015 $)	Annual Dam. pp (% GDP in 2100)	GDP pp in 2100 (% GDP in 2020)	GDP pp in 2100 with damages (% GDP in 2020)
RCP 4.5 damages	SSP 1	3.0	2.7	$ 53,040	$ 139,384	$ 475	0.34%	263%	262%
RCP 4.5 damages	SSP 2	3.8	2.6	$ 53,326	$ 126,908	$ 483	0.38%	238%	237%
RCP 4.5 damages	SSP 3	4.1	2.6	$ 52,424	$ 121,374	$ 846	0.70%	232%	230%
RCP 4.5 damages	SSP 4	3.8	2.5	$ 53,867	$ 133,451	$ 607	0.45%	248%	247%
RCP 4.5 damages	SSP 5	5.1	2.7	$ 53,048	$ 189,739	$ 310	0.16%	358%	357%
RCP 8.5 damages	SSP 5	5.1	5.1	$ 53,048	$ 189,739	$ 712	0.38%	358%	356%
RCP 8.5 high damage	SSP 5	5.1	5.1	$ 53,048	$ 189,739	$ 18,974	10.00%	358%	322%

Damages from FNCA (2018; Fig 29.2). High damage scenario from FNCA (2018, Fig 29.3). SSP scenarios from IIASA database, IIASA GDP series. Riahi et al. (2017) shows that only the SSP 5 baseline scenarios of three models (AIM/CGE, REMIND-MAGPIE and WITCH-GLOBIOM) can reach the 8.5 W/m2 radiative forcing level by 2100. RCP 4.5 scenarios include cost of damages but do not include cost of mitigation for simplicity.

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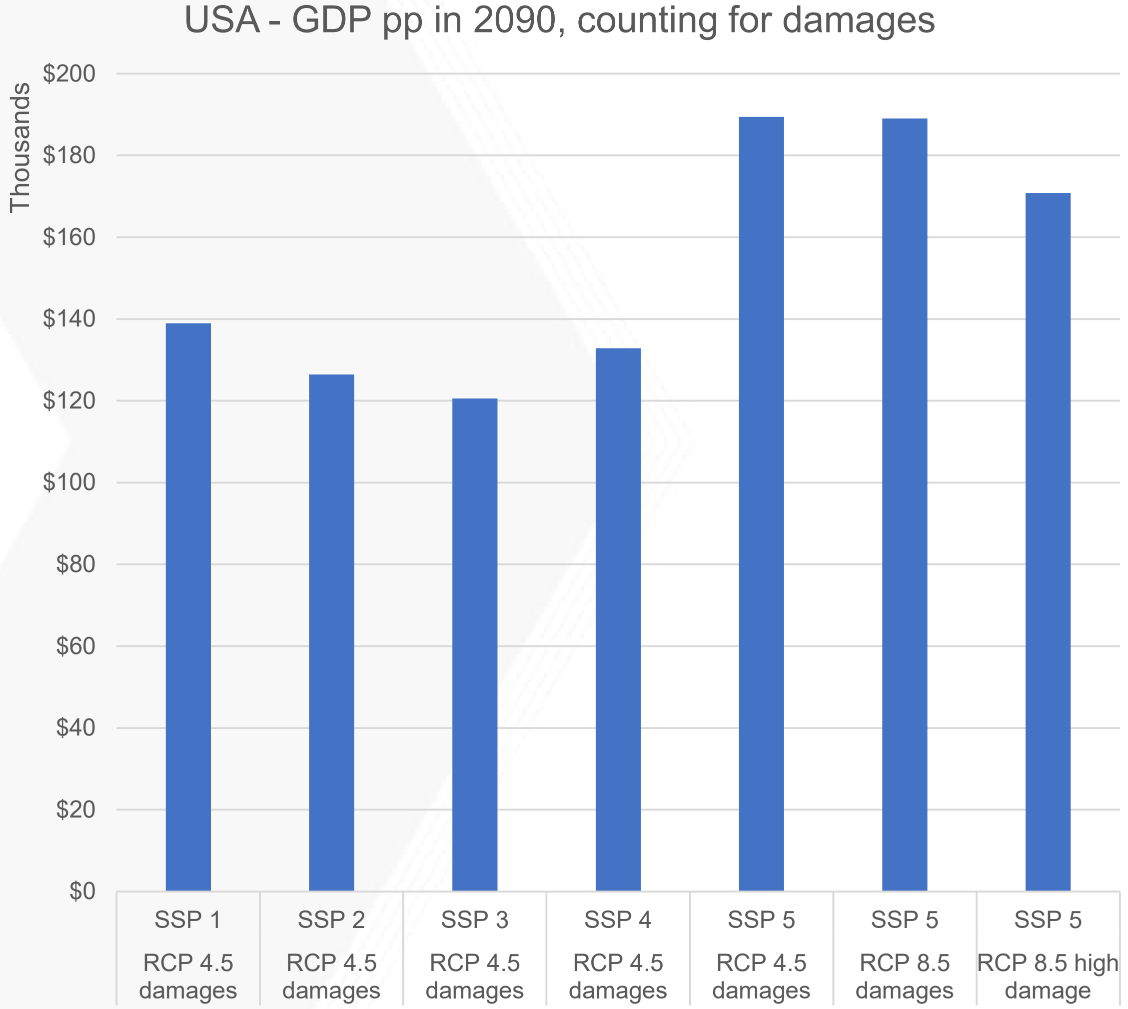
Latin America

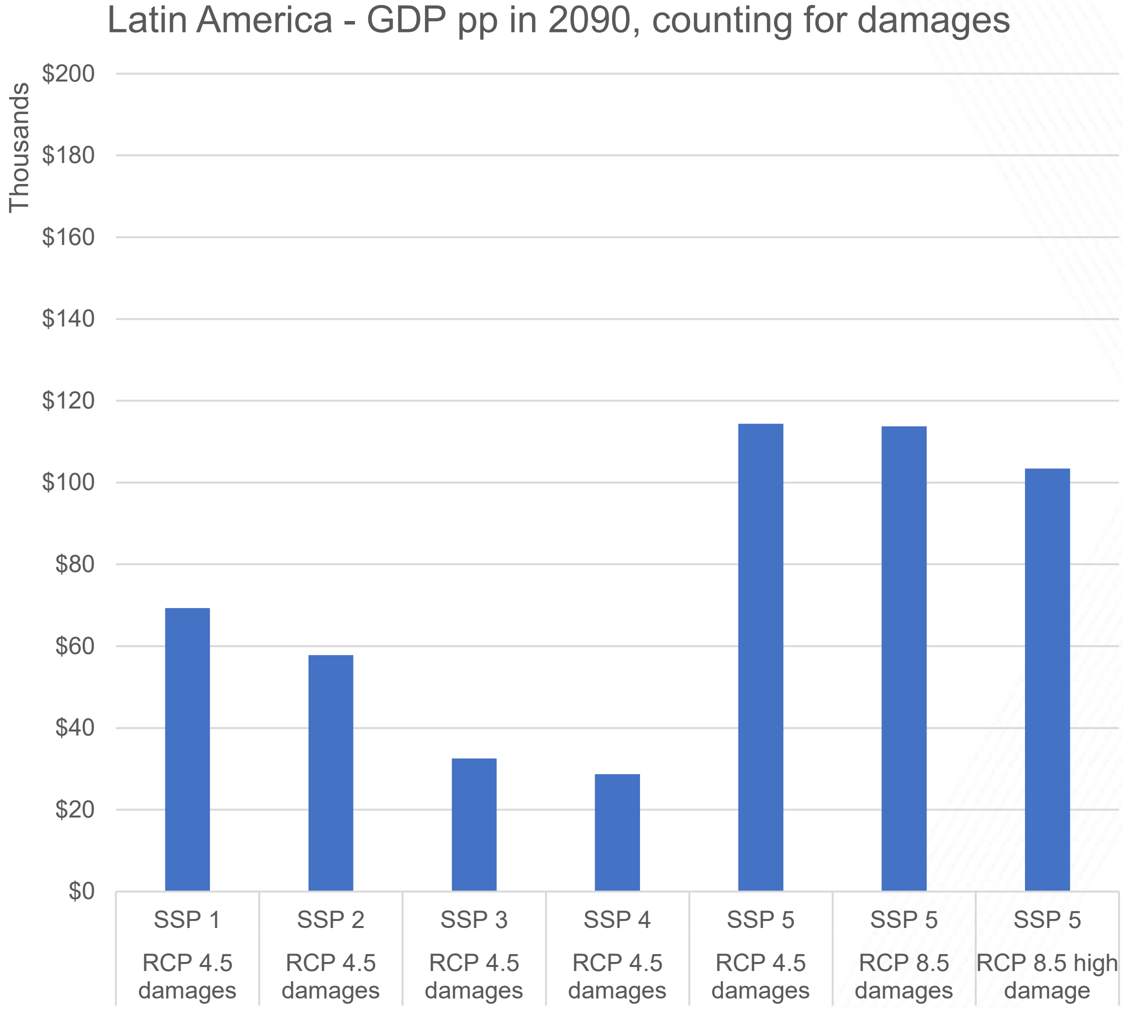
RCP	SSP	ΔT (°C) (baseline)	ΔT (°C)	GDP in 2020 (Billion 2015 $)	GDP in 2100 (Billion 2015 $)	Damages in 2100 (Billion 2015 $)	Annual Damages (% GDP in 2100)	GDP in 2100 (% GDP in 2020)	GDP in 2100 with damages (% GDP in 2020)
RCP 4.5 damages	SSP 1	3.0	2.7	$ 9,376	$ 33,725	$ 221	0.66%	360%	357%
RCP 4.5 damages	SSP 2	3.8	2.6	$ 9,269	$ 38,917	$ 221	0.57%	420%	417%
RCP 4.5 damages	SSP 3	4.1	2.6	$ 9,190	$ 35,247	$ 221	0.63%	384%	381%
RCP 4.5 damages	SSP 4	3.8	2.5	$ 8,946	$ 16,378	$ 221	1.35%	183%	181%
RCP 4.5 damages	SSP 5	5.1	2.7	$ 9,420	$ 51,758	$ 221	0.43%	549%	547%
RCP 8.5 damages	SSP 5	5.1	5.1	$ 9,420	$ 51,758	$ 508	0.98%	549%	544%
RCP 8.5 high damage	SSP 5	5.1	5.1	$ 9,420	$ 51,758	$ 5,176	10.00%	549%	495%

RCP	SSP			GDP pp in 2020 (2015 $)	GDP pp in 2100 (2015 $)	Damages pp in 2100 (2015 $)	Annual Dam. pp (% GDP in 2100)	GDP pp in 2100 (% GDP in 2020)	GDP pp in 2100 with damages (% GDP in 2020)
RCP 4.5 damages	SSP 1	3.0	2.7	$ 14,797	$ 69,738	$ 458	0.66%	471%	468%
RCP 4.5 damages	SSP 2	3.8	2.6	$ 14,418	$ 58,150	$ 331	0.57%	403%	401%
RCP 4.5 damages	SSP 3	4.1	2.6	$ 14,030	$ 32,702	$ 205	0.63%	233%	232%
RCP 4.5 damages	SSP 4	3.8	2.5	$ 13,982	$ 29,058	$ 393	1.35%	208%	205%
RCP 4.5 damages	SSP 5	5.1	2.7	$ 14,936	$ 114,883	$ 491	0.43%	769%	766%
RCP 8.5 damages	SSP 5	5.1	5.1	$ 14,936	$ 114,883	$ 1,127	0.98%	769%	762%
RCP 8.5 high damage	SSP 5	5.1	5.1	$ 14,936	$ 114,883	$ 11,488	10.00%	769%	692%

Damages from FNCA (2018; Fig 29.2). High damage scenario from FNCA (2018, Fig 29.3). SSP scenarios from IIASA database, IIASA GDP series. Riahi et al. (2017) shows that only the SSP 5 baseline scenarios of three models (AIM/CGE, REMIND-MAGPIE and WITCH-GLOBIOM) can reach the 8.5 W/m2 radiative forcing level by 2100. RCP 4.5 scenarios include cost of damages but do not include cost of mitigation for simplicity.

In Which World Would You Prefer Living?





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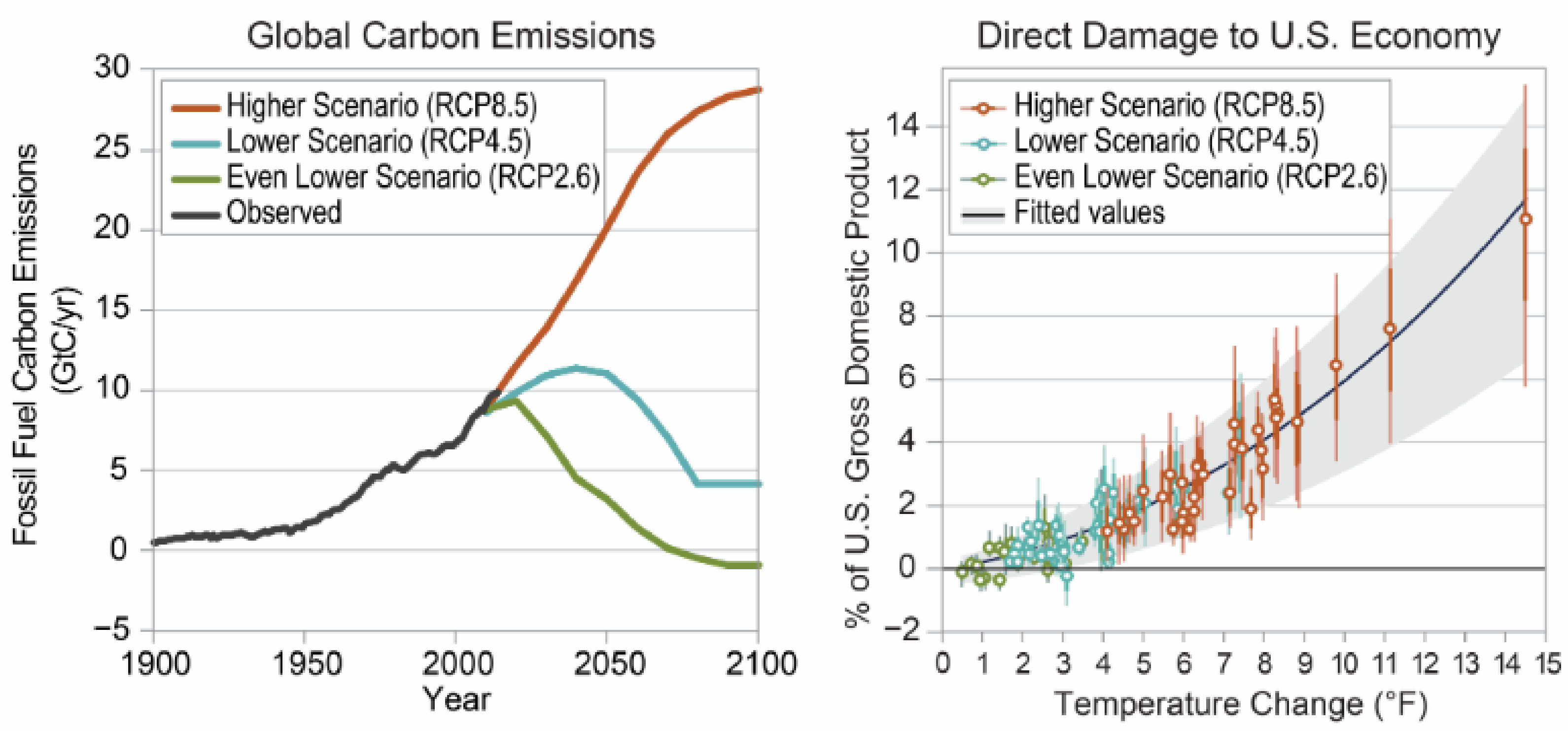
NCA4. Chapter 29. Figure 29.3

Figure 29.3 Estimates of Direct Economic Damage from Temperature Change



NCA4. Report in Brief. Ch 29.

What Happened?

- Figure from one study in the literature, not assessed by the NCA4 team
- This study assumes
  - No adaptation at all
  - Questionable assumptions on growth effects
  - Model misspecification: identified using weather shocks instead of climate averages

- In fact, the 10% figure is not explicitly endorsed and contradicts NCA4 own assessment
- The figure is used to provide an example of how mitigation can reduce uncertainty around impacts (in a way that is not quite correct)
  - *"Looking at the economy as a whole, mitigation can substantially reduce damages while also narrowing the uncertainty in potential adverse impacts (Figure 29.3)."*

- Less than ideal report writing amplified by confirmation bias in reporting

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Three Important Take-Away Messages

1. Technical progress, trade and sound institutions main drivers of economic progress

2. Climate change impacts appear to be of second-order importance

3. Careful balance of benefits and costs of climate mitigation, considering all risks and uncertainties

A question of balance

"Actually from an economic point of view, it's a pretty simple problem."

https://www.npr.org/2014/02/11/271537401/economist-says-best-climate-fix-a-tough-sell-but-worth-it

Efficient Abatement

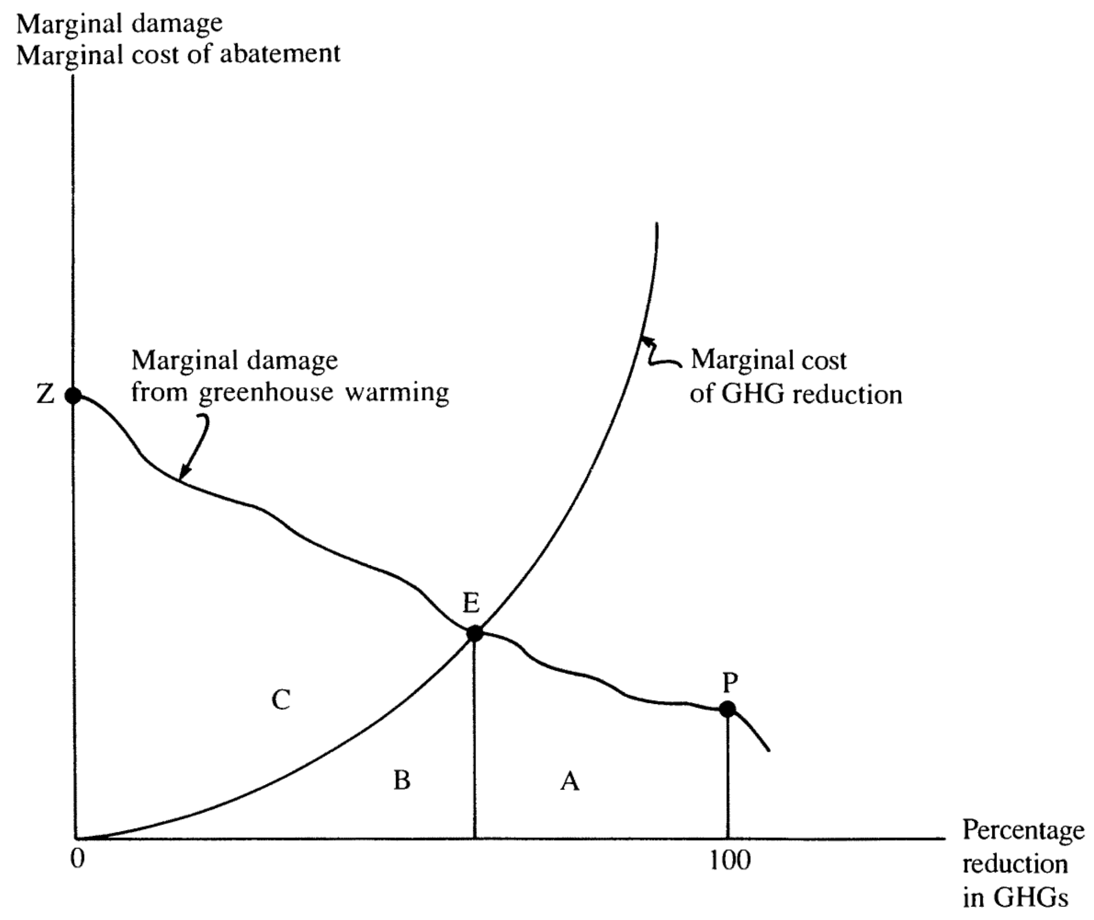

Fig. 1. Marginal costs of GHG reductions and marginal damage from GHG emissions.

The Economic Journal, 101 (*July* 1991), 920–937
Printed in Great Britain

TO SLOW OR NOT TO SLOW: THE ECONOMICS OF THE GREENHOUSE EFFECT

William D. Nordhaus

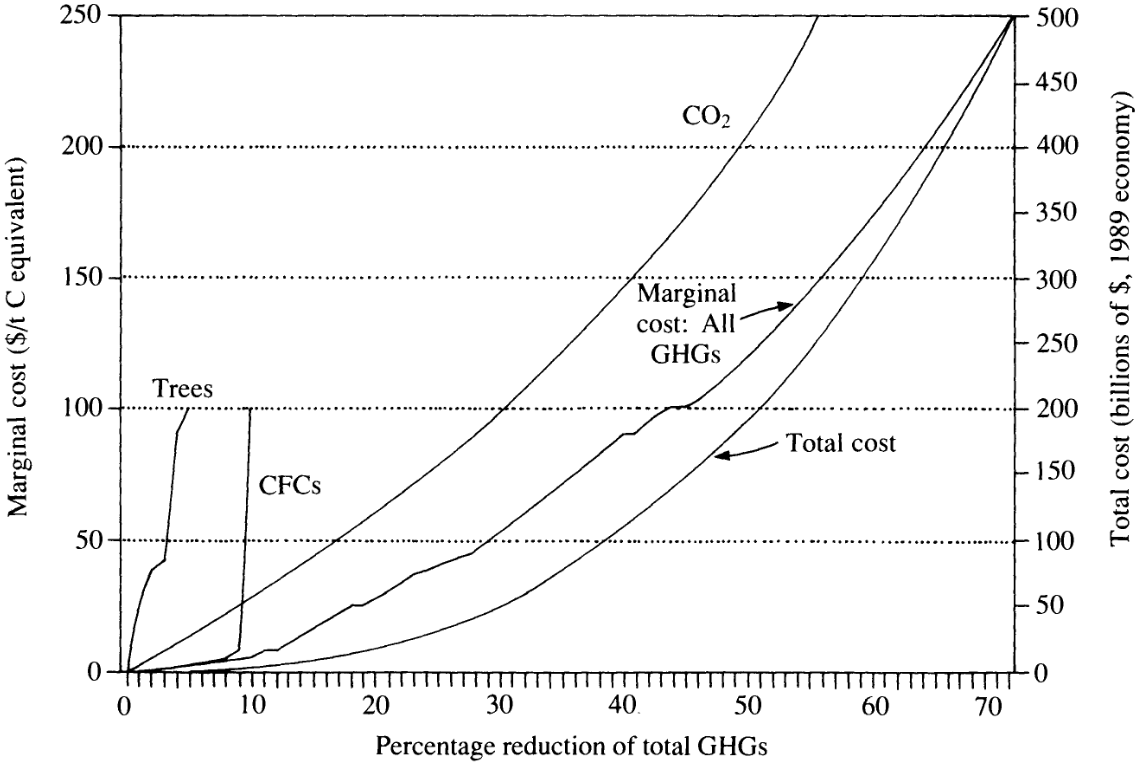

Fig. 2. Marginal and total costs of GHG reduction.

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Climate Change Impacts and Adaptation

"Projecting impacts is the most difficult and has the greatest uncertainties of all the processes associated with global warming."

- Key role of adaptation: optimal adjustments to minimize (maximize) harmful (beneficial) effects of climate change

- Most important driver of adaptation is rising income per capita

"Human societies increasingly devote resources to insulate their lives and property from environmental conditions as their incomes rise."

All citations from Nordhaus (2014) "The Climate Casino", Yale University Press.

Adaptation potential

Extensively Managed Systems	Partially Managed Systems	Unmanageable Systems
Most economic sectors: • Manufacturing • Health Care Most human activities • Sleeping • Surfing the intenet	Vulnerable economic sectors: • Agriculture • Forestry Nonmarket systems: • Beaches and coastal ecosystems • Wildfires	Hurricanes Sea-level rise Wildlife Ocean acidification

Increasing challenges and potential failure for adaptation

Why Losses up to 10% of the US Economy are Unlikely

- A new literature finds large damages because it assumes there will be no adaptation
  - No effects of increased income on adaptation potential

- Identification of random weather shocks, not climate change
- In stark contrast with Nordhaus' work on climate damages

climate would be as a dynamic, stochastic system of equations. The probability distributions of the atmospheric characteristics is what we mean by climate, while a particular realization of that stochastic process is what we call the weather.

Nordahus (1977). Strategies for the Control of Carbon Dioxide. Cowles Foundation Discussion Paper No. 443.

"In estimating impacts, people often confuse weather and climate."

Nordahus (2014). The Climate Casino. Yale University Press, p. 75.

Discounting

- One of the most controversial issues in climate change policy debate

- $100 invested today at a real interest rate equal to 4.5%, by 2218 grows to…

$ 665,669

- How much are you willing to give up today to receive $ 665,669 in 2218?

$ 10

Discounting

- As individuals we discount future monetary benefits
- Two reasons:
  - We are impatient
    - Pure rate of time preference (d)
  - If we think our income will grow, $1 in the future counts less than $1 today
    - How much we discount depends on how adverse we are to inter-temporal income inequality (e) and on the expected growth rate of the economy (g)
- The discount rate r is set by the following formula

$$r = d + g \times e$$

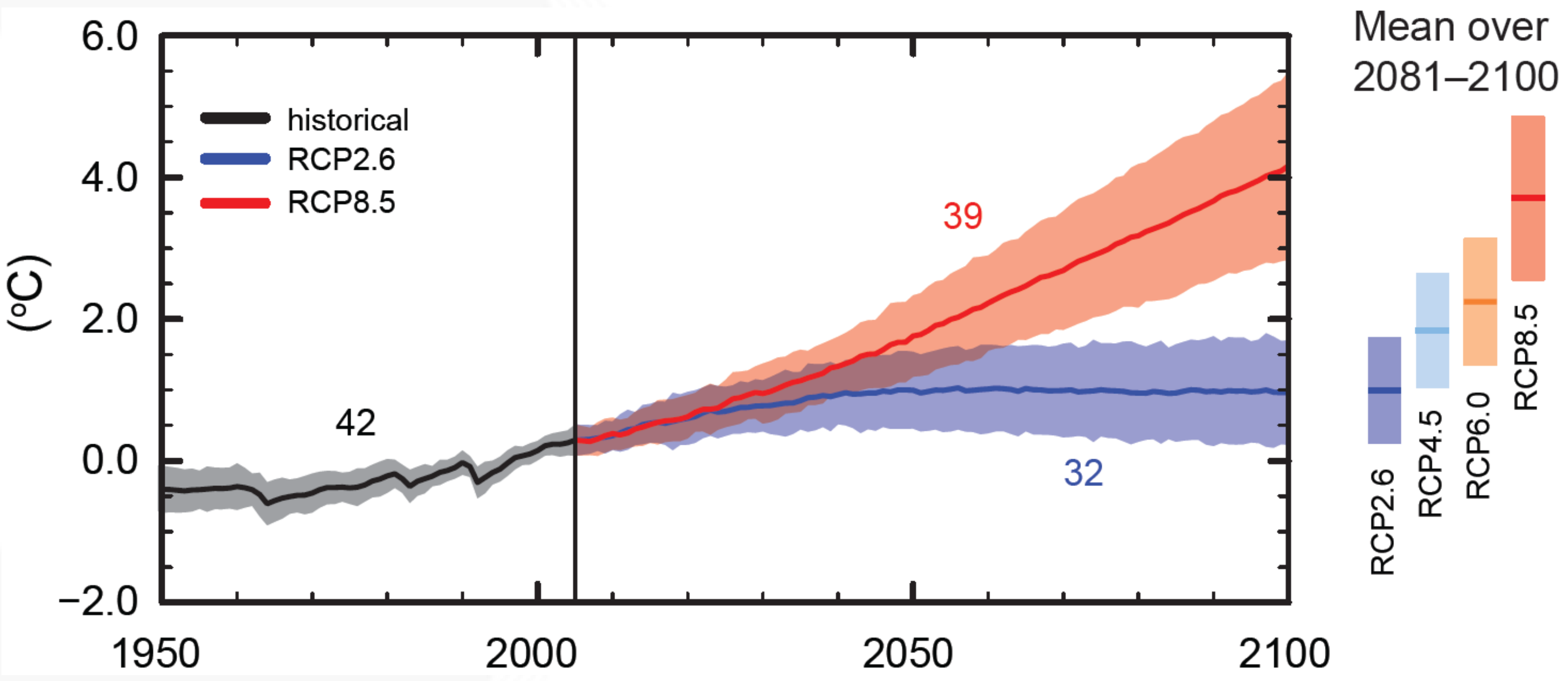
The Effect of Discounting on Climate Change Policy

- Mitigation costs are upfront
- Benefits of emission reductions come late in the century
  - Strong inertia of the climate system
  - Increased warming

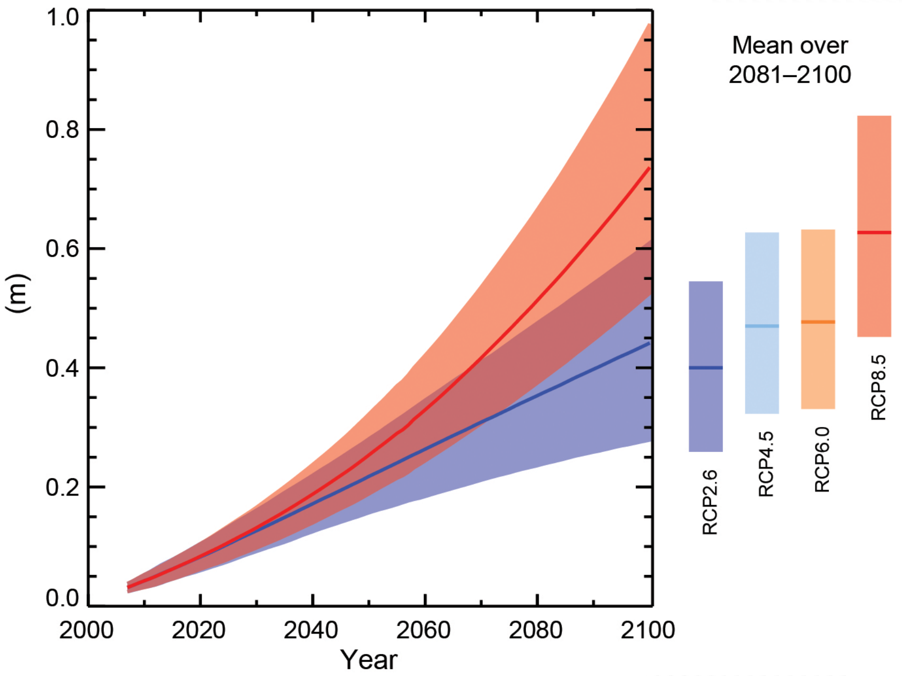
- Discounting reduces the relative importance of benefits and suggests a moderate approach to emission reductions

- The faster is economic growth, the larger the emissions, the larger the climate damages, the larger the discount rate…

Extreme Inertia of the Climate System



IPCC AR5, Figure SPM.7, Panel a



IPCC AR5, Figure SPM.8, Panel d

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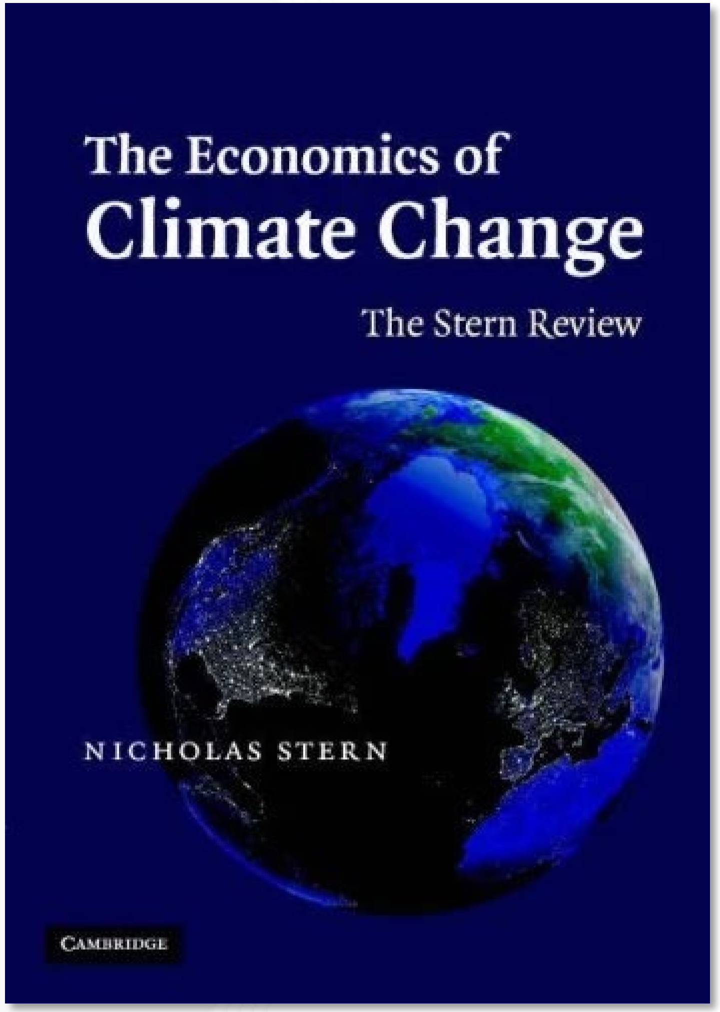
The Stern Review



- Very large damages at the end of the century
- Very low discount rate (*r*)
- Large emission reductions are optimal starting from now

Nordhaus and the Stern's Review of Climate Change

$$r = d + g \times e$$

Journal of Economic Literature
Vol. XLV (September 2007), pp. 686–702

A Review of the *Stern Review on the Economics of Climate Change*

William D. Nordhaus*

- Observed values for r and g are equal to about 4 – 4.5% and 3%, at global level
- e can be estimated
- d is determined as a residual, approximately 1.5%

- In the Stern Review d is chosen to be equal to 0.1% and e is not adjusted to give observed values for r and g
  - The Stern Review uses inconsistent assumptions

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Discounting, Ethical Considerations

- No discounting leads to a paradox:
  - Future generations have infinite importance
  - We would be crushed under the burden of an infinite number of descendants

- Even if we treat all generations equal, growing incomes for future generations are a good reason for discounting

- Real problem is if income declines
- However, a declining global economy fixes the climate problem without need for policy

- The theoretical framework can accommodate many different assumptions, what matters is consistency

Policy

"We need to put a price on carbon, so that when anyone, anywhere, anytime does something that puts carbon dioxide in the atmosphere, there's a price tag on that," he says.

His colleagues say that inspiration—now taken for granted—makes Nordhaus a prime candidate for a Nobel Prize.

https://www.npr.org/2014/02/11/271537401/economist-says-best-climate-fix-a-tough-sell-but-worth-it

The Social Cost of Carbon

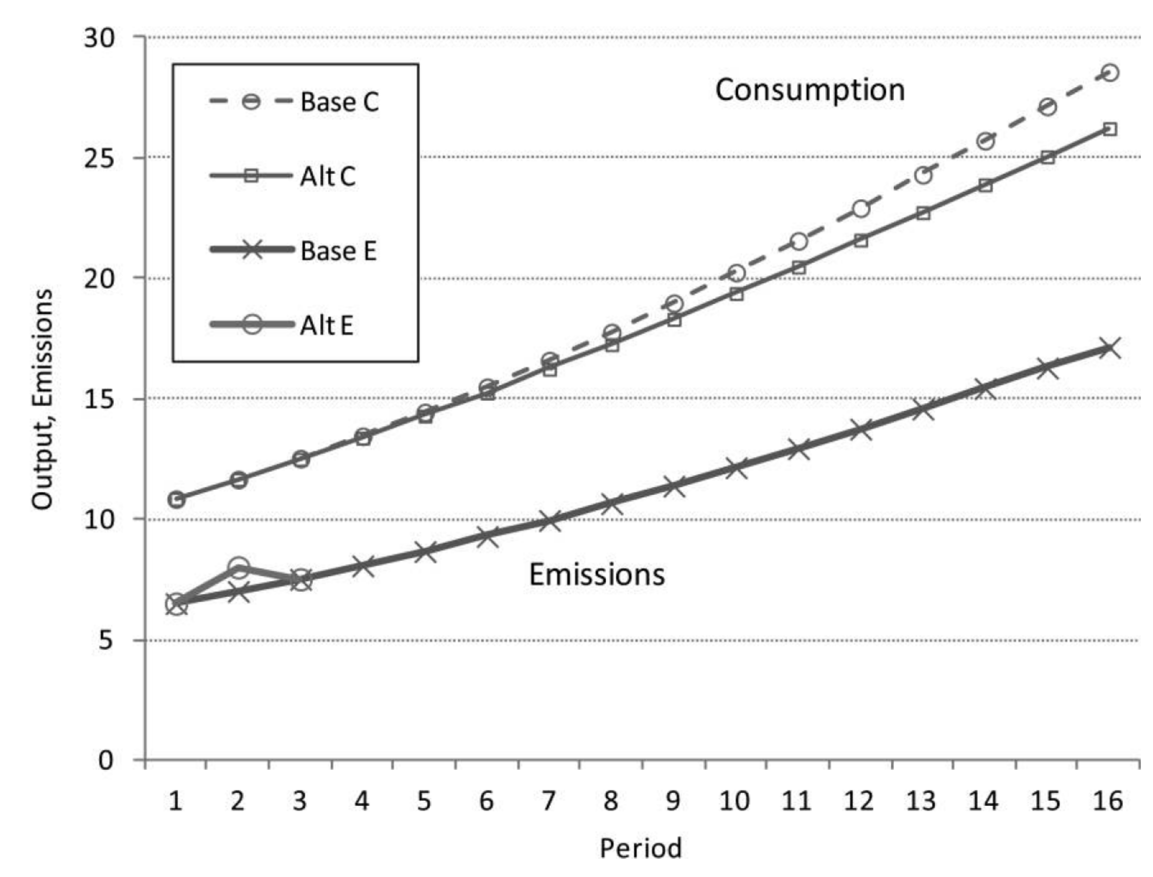


Table 1. Global Social Cost of Carbon under Different Assumptions

Scenario	2015	2020	2025	2030	2050
Base parameters:					
Baseline*	18.6	22.1	26.2	30.6	53.1
Optimal controls†	17.7	21.2	25.0	29.3	51.5
2°C limit damage function:					
Maximum†	47.6	60.1	75.5	94.4	216.4
Max of average†	25.0	30.6	37.1	44.7	87.9
Stern Review discounting:					
Uncalibrated*	89.8	103.7	117.4	131.3	190.0
Calibrated*	20.7	25.0	30.1	35.9	66.9
Alternative high discount*	6.4	7.7	9.2	10.9	19.6

Note.—The social cost of carbon is measured in 2005 international US dollars. The years at the top refer to the date at which emissions take place. Therefore, $18.6 is the cost of emissions in 2015 in terms of consumption in 2015.

* Calculation along the reference path with current policy.

† Calculation along the optimized emissions path.

Regional Costs of Carbon

Table 2. Region Social Costs of Carbon

Region	Emissions (Billions of Tons CO_2, 2005)	SCC (2015)	Percent of Global SCC		
			RICE 2010 (U)	FUND 2013	PAGE 2011
United States	6.11	1.94	10	17	7
European Union	4.14	2.32	12	24	9
Japan	1.28	.43	2	3	NA
Russia	1.54	.18	1	10	NA
Eurasia	.92	.16	1	NA	NA
China	6.14	3.02	16	8	11
India	1.48	2.21	12	5	22
Middle East	2.14	1.89	10	NA	NA
Africa	.69	2.09	11	6	26
Latin America	1.54	1.30	7	NA	11
OHI	1.93	.74	4	NA	NA
Other	1.38	2.29	12	NA	NA
Weighted country average		1.92			
Global	29.30	18.6	100	100	100

- Strong incentives to adopt a patchwork of policies
- Domestic damages a fraction of global damages
- US SCC uses global damages
  - Unclear legal framework
  - Can be challenged in courts

Catastrophic Thresholds

Table 4. Social Cost of Carbon with Catastrophic Threshold, with and without Climate Policy

	Social Cost Carbon (2015 in 2005$)	
Threshold Temperature, T^*	With Optimal Policy	With No Policies for 100 Years
1.5°C	125	1,495
2°C	54	1,046
3°C	24	197
4°C	19	33

Note.—The cases without policy assume no abatement for a century. The cases with policy assume immediate optimal abatement. The catastrophic damage function assumes that the damage-output ratio is $0.01(T(t)/T^*)^8$, where T^* is the catastrophic threshold.

- Optimal policy
  - SCC calculated assuming optimal mitigation
- No policy
  - SCC calculated assuming business as usual
  - Contradiction: SSC is in fact used for mitigation
- Threshold effects not dramatic if one considers the optimal policy SCC

Why a Carbon Tax and Not Subsidies?

- A tale of two externalities
  - A negative one: GHG emissions
  - A positive one: knowledge diffusion

- A global carbon tax, uniform across all sectors and countries is the efficient policy tool to fix the environmental externality
- The carbon tax should not be substituted with an innovation subsidy

- Subsidies to innovation are needed to fix the knowledge externality
  - However, as all sectors suffer from this problem, this should be part of industrial/R&D policies, not climate change policy per se

Conclusions

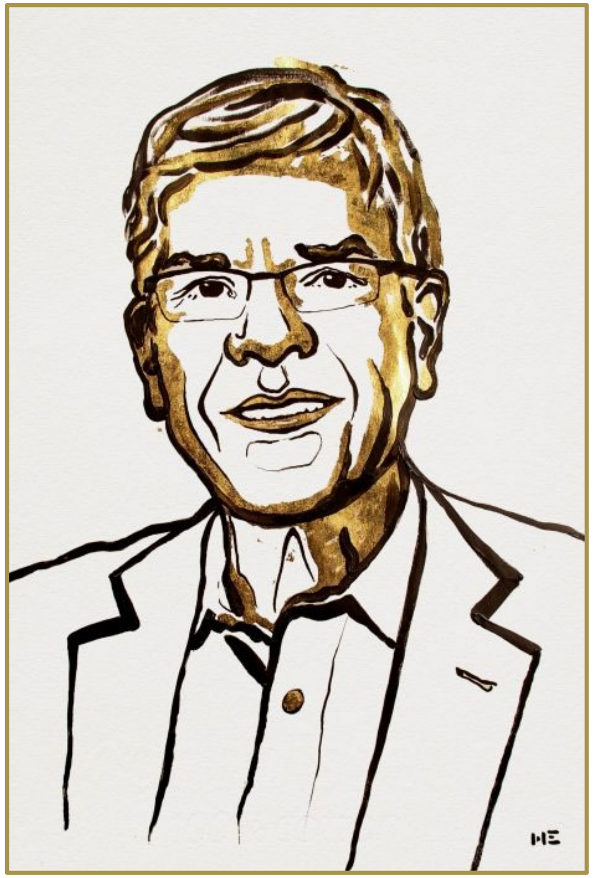
My personal final thoughts…

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2018

Ill. Niklas Elmehed. © Nobel Media

William D. Nordhaus

"for integrating climate change into long-run macroeconomic analysis"



Ill. Niklas Elmehed. © Nobel Media

Paul M. Romer

"for integrating technological innovations into long-run macroeconomic analysis."

MLA style: The Prize in Economic Sciences 2018. NobelPrize.org. Nobel Media AB 2018. Mon. 26 Nov 2018.

The Long-Run Effect of Climate Change on Growth

- Paul Romer has introduced endogenous technical change in growth models

- Innovation, new ideas are at the core of economic growth
- Innovation is the engine of growth and will determine the fate of future generations

- Climate change is going to catastrophic effects only if it will stop the engine of innovation
  - Widespread geo-political disruptions
  - Collapse of institutions that have supported economic progress
  - A return to the Middle Ages, as after the end of the Roman Empire

"At some point you move from 'calm' to 'concerned,' " he says. "I'm not at 'panic,' but there are some pretty deep concerns about what's going on — particularly at the slow pace of the steps that countries are taking to deal with climate change."

https://www.npr.org/2014/02/11/271537401/economist-says-best-climate-fix-a-tough-sell-but-worth-it

Thank you!

emanuele.massetti@gatech.edu